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BIDIRECTIONAL PV-POWERED BATTERY CHARGER FOR ELECTRIC VEHICLE

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Abstract:

In the automotive industry, electrical vehicles (EVs) are a relatively new technological development. The majority of cars on the road today run on fossil fuels like gasoline and diesel, which pollutes the environment by raising CO2 and other harmful gas emissions. Additionally, there is a growing scarcity of fossil fuels. Electric vehicles are introduced as a solution to the aforementioned problem. The bidirectional DC-DC buck-boost converter modeling and analysis for battery energy storage systems and photovoltaic panels are presented in this work. PV panels operate based on the available irradiance. The PV array will use a bidirectional DC-DC converter to charge the battery and supply power to the load when the irradiance increases enough to generate that voltage. The battery will supply the load using the same bidirectional DC-DC converter when the PV array's irradiance is insufficient to create a suitable voltage, at which point the battery will drain through the load. Since traditional buck or boost converters are incapable of producing bidirectional power flow, buck and boost converters are connected in opposition to one another to create a bidirectional DC-DC power flow converter. This study presents the voltage across the load and the battery's charging and discharging behavior in relation to the availability of irradiance. Various proportional integral controllers are modeled and designed to generate the required duty cycle for MOSFET/IGBT switches in order to obtain satisfactory results.

Keywords — **Battery, DC-DC converter, voltage, current.**

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I. INTRODUCTION

A solar cell is another name for a photovoltaic cell. The photovoltaic effect is used to create the phenomena of light energy being converted into electrical by use of a solar cell. A PV array is a collection of photovoltaic (PV) modules that are created by connecting PV cells in parallel or series, depending on the amount of electricity needed. The light irradiance, light wavelength, angle of incidence of irradiance on PV array, PV array material, and PV array area are the primary factors that affect the voltage generated by the PV array. Solar arrays have several major obstacles, including those related to photovoltaic material, cost, installation, maintenance, and efficiency. Since the availability of irradiance is a major component in the operation of a photovoltaic array, its efficiency decreases significantly when irradiance is absent. By combining a bidirectional DC-DC converter and BESS with a PV array, the efficiency of the PV array can be increased. Because of the constant fluctuation in irradiance, the voltage generated by the PV array is variable in nature. In PV arrays and bidirectional DC-DC converters, a DC link capacitor serves as both a coupling element and a filter. It raises the caliber of voltage that the PV array produces. A DC-DC converter is a device that has one or more energy-storing, filtering, high-frequency switches, and produces DC voltage upon application of DC input voltage. DC-DC converters can be classified as either isolated or non-isolated depending on whether an electrical isolating element, such as a transformer, is present.

Depending on the arrangement, DC-DC converters can step-up or step-down the input voltage. The bidirectional power flow capability, which is a crucial prerequisite for using a standard DC-DC converter for battery charging and discharging, is absent from a typical DC-DC buck or boost converter. The modeling and analysis of bidirectional DC-DC converters for the BESS and PV array are presented in this study. Different voltage and current PI controllers are used to regulate the bidirectional DC-DC converter. Because MOSFET/IGBT has a high switching frequency and minimal switching losses, it is preferred over other switches. In this research, MOSFET is employed as a switch because it has an anti-parallel diode that can be used as a free-wheeling diode when the switch is off.

II. BIDIRECTIONAL BATTERY CHARGER CIRCUIT

The AC/DC converter and DC/DC converter are essential parts of an EV bidirectional battery charger. When an EV is charging, an AC/DC bidirectional converter converts the DC power from the battery to AC electricity, which is then injected into the grid when the EV is discharging. Conversely, the DC/DC converter is in charge of employing the direct current control approach to regulate the bidirectional power flow. In charging or discharging mode, it functions as a buck or boost converter. A transportable, two-way battery charger that will be used in vehicle-to-grid (V2G) and grid-to-vehicle (G2V) scenarios. The rectifier circuit is linked to a reversible DC-DC converter circuit that generates a buck or boost effect for charging and discharging by combining two more IGBTs with an inductor and capacitor.

A. *CIRCUIT DIAGRAM*

With MATLAB/Simulink, a non-isolated bidirectional DC-DC buck-boost converter is modeled and designed. Fig. displays the bidirectional DC-DC converter circuit diagram. Two diodes, D1 and D2, are linked in anti-parallel with two switches, S1 and S2, respectively, to form this converter. There are two modes of operation for this bidirectional DC-DC converter: buck and boost.

Buck mode: The bidirectional converter runs in buck mode when switch S1 and diode D2 are on and switch S2 and diode D2 are off.

Boost mode: It functions in boost mode when switch S2 and diode D1 are turned on and switch S1 and diode D2 are turned off.

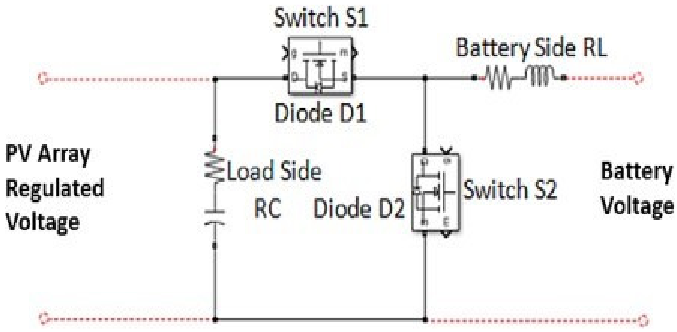


Fig: Bidirectional battery charger circuit Using PV

A bidirectional DC-DC converter connects the battery and photovoltaic array. Through a bidirectional DC-DC converter, power can move from the load to the BESS and vice versa. When there is enough available irradiance to generate the necessary voltage for the load, power moves simultaneously from the PV array to the BESS and the BESS charges. The bidirectional converter will now function in buck mode. When the available irradiance cannot provide the necessary voltage for the load, power moves from the BESS to the load, and the BESS then discharges. Bidirectional DC-DC converters are now operating in boost mode.

TABLE I
BIDIRECTIONAL CIRCUIT PARAMETERS

S.NO	Parameter name	Parameter value
1	Input voltage	800V
2	Bus capacitor	1000uf
3	Switching frequency	50Khz
4	Filter inductor	13mh
5	Filter capacitor	20uf
6	Battery nominal voltage	360V
7	Battery rated current	150AH

III. MODES OF OPERATIONS

There are four ways that a bidirectional battery charging circuit can function. There are two ways that buck converters can operate when charging batteries. The boost converter has two operating modes and is used for battery discharging.

B. Battery charging operation

1) Mode 1

It functions in the initial two quadrants. It is a bidirectional device that can function in boost and buck modes separately. When used as a voltage reducer, the converter operates in two stages, just like a conventional non-isolated buck converter.

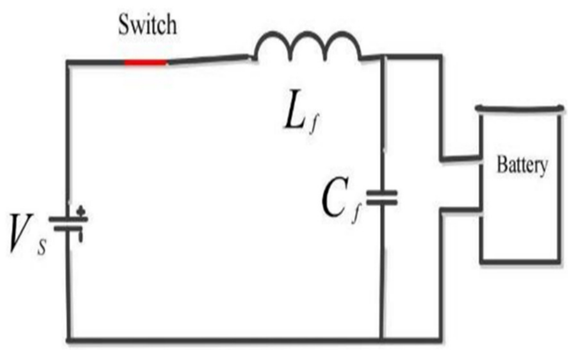


Fig 2.2: MODE 1 operation buck converter

All A DC-to-DC converter that increases current from its input to its output while decreasing voltage is known as a buck converter or step-down converter. It belongs to the switched mode power supply class. Comparing switching converters to linear regulators, which are more straightforward circuits that release energy as heat but do not increase output current, the former offer significantly higher power efficiency as DC-to-DC converters.

2) Mode 1

Figure illustrates how the buck converter operates in mode 1. SI is tuned ON, S2 is tuned OFF, and both diodes are off in this configuration. The buck converter's Mode-11 is shown in Fig. functioning in this mode; both switches deactivate switches 1 and 2. Diode 1 is off and diode D2 is on.

voltage output of a Buck Converter

$$V0 = (ton)/T \ Vs \qquad (1)$$

$$V0 = DVs \qquad (2)$$

Equations (1) and (2) show the buck converter's output voltage. Duty cycle is represented by the output voltage V0, supply voltage Vs, total time T, and switch on time ton D.

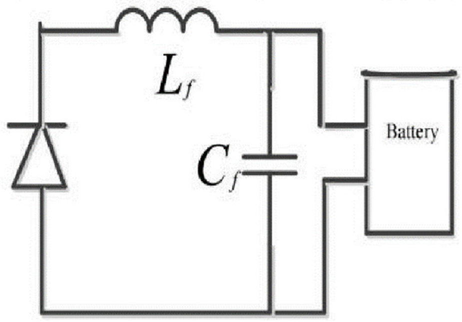


Fig: MODE 2 operation buck converter

A diode and a transistor are the two semiconductors that most buck converters have in common, while more recent models usually replace the diode with a second transistor for synchronous rectification and at least one energy storage component, such as an inductor, capacitor, or both combined. Filters consisting of capacitors, often in conjunction with inductors, are typically added to the input supply side filter and output load-side filter of such a converter to reduce voltage ripple.

The 30A reference current battery charging mode. The output is almost exactly at 29.52A. In battery charging mode, the demonstrated controller functions flawlessly. The battery nominal voltage, battery charging voltage, battery reference voltage, and battery current are displayed in table 3.2.

C. Battery charging mode waveform

Battery charging mode output waveforms are displayed in Fig. These waveforms show the minimum and maximum currents, I1 and I2, and the input supply voltage, Vs. I0 is represented by the output current. The time is 0 to k T in the output waveforms mode -1 operation. The load is connected to this duration input voltage. While the output current is kept constant, the inductor current rises from I1 and I2. The output current is kept constant, the supply voltage is zero, and the inductor current drops from I2 to I1 when operating in mode 11. B.

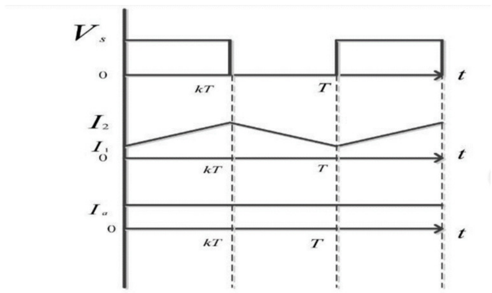


Fig: Battery charging mode waveform

D. System modelling

Figures The suggested bidirectional DC-DC Buck-Boost converter system with BESS and PV array is modeled and laid out using MATLAB/Simulink. Fig. displays the block diagram of the suggested system with its different components.

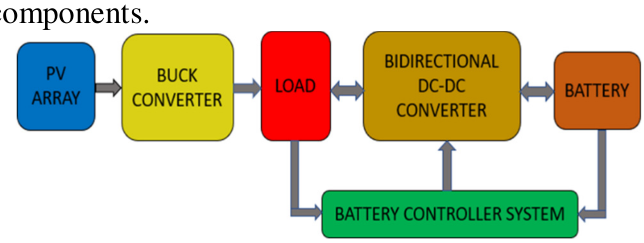
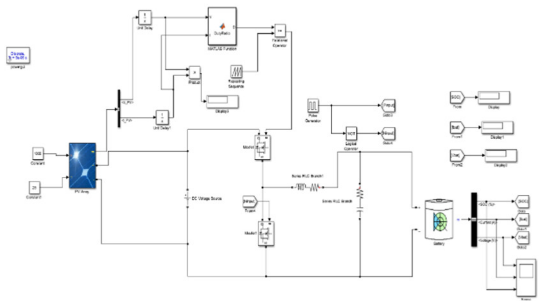


Fig: Block Diagram for Proposed System

E. Simulation result

PV Array connected buck converter, connection switch, bidirectional DC-DC converter, voltage control charge PI controller, voltage control discharge PI controller, current control PI controller, and logic switch are the primary subsystems of this MATLAB/Simulink system. Three parallel strings and three series-connected modules per string make up the PV Array used in MATLAB/Simulink. The PV array that is being used has an irradiation of 1000 W/m2 for 0 to 5 seconds and 200 W/m2 for 5 to 10 seconds. The simulation is conducted at a constant 25℃ temperature. The links between various sub-systems are displayed in Fig. below.



A logic switch is added to the MATLAB/Simulink model, allowing for automatic control of the battery's charging modes based on the logic switch's defined threshold voltage.

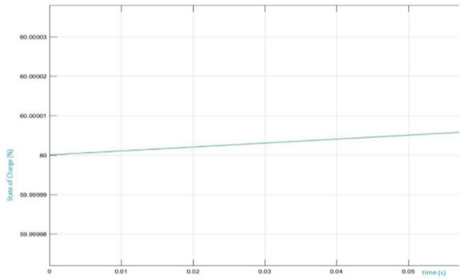


Fig State of charge waveform of charging mode

The battery state of charge (SOC% vs. time) graph is produced following the simulation of the regenerative braking operation mode. The graph's design validates the battery's intended charging state.

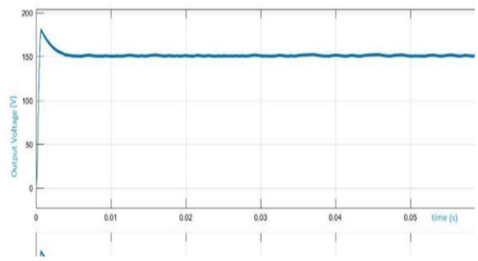


Fig Output voltage waveform of charging mode

It shows the voltage stress on switches S1, S2, and S3. It is observed that when S1 is in OFF condition, a maximum of around 97 V appears across it. It is found to be around 60 % of the total output load voltage.

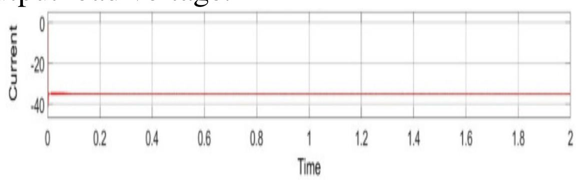


Fig Output current waveform of charging mode

IV. CONCLUSIONS

Electric vehicles are the way of the future for daily commutes as well as for other forms of transportation, including commercial and mass transit as well as passenger cars and bikes utilized for daily household needs. Although electric vehicles have long been seen as a means of transportation for the future, the demand for electricity-based commuter vehicles has increased due to the need to protect the environment.

With the help of the intended bidirectional DC-DC buck-boost converter, the battery has been charged. PV array power is nearly 1500W at its greatest power point, which MATLAB/Simulink allows for. The PV array's efficiency has grown as a result of MATLAB/Simulink's ability to achieve the maximum power point condition. When there is a transient in irradiance at t = 5 seconds, there is also a brief transient in load voltage; once again, the load voltage returns to 48 volts as needed within the safe duration. Throughout the simulation, the generated load voltage is 47.5 to 48.5 volts, which is substantially closer to the needed load voltage. The ripple generated by the load voltage is a very small 2%.

FUTURE SCOPE

Advancements in technology and market trends come together to create bidirectional battery chargers for electric vehicles that use buck-boost converters. Enhancing efficiency will be a top priority, and attempts to reduce energy loss during the charging and discharging operations will not stop. Another important area of research is integration with Vehicle-to-Grid (V2G) systems, which allow electric vehicles to both take power from and return excess energy to the grid. In order to optimize charging and discharging depending on vehicle usage patterns and grid circumstances, advanced control algorithms will be essential. Cost savings are anticipated as production increases and technology advances, enabling bidirectional chargers to be more widely available to consumers. Additionally crucial to maintaining compatibility between various chargers and electric cars will be standardization efforts. As always, the top priorities will be safety and dependability, with a strong emphasis on safeguards against overcharging and short circuits. In general, there is a great deal of promise for bidirectional battery chargers for electric vehicles that use buck-boost converters in the future. These benefits include increased safety and dependability, cost savings, integration with V2G systems, and efficiency gains.

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